RESULTS OF SPACE SHUTTLE FLIGHT 41–C

HEARING

BEFORE THE

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RESULTS OF SPACE SHUTTLE FLIGHT 41-C

TUESDAY, MAY 15, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The committee met, pursuant to notice, at 10:06 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the committee) presiding.

Present: Representatives Fuqua, Winn, Brown, Walker, McGrath, Walgren, Skeen, Glickman, Schneider, Chandler, Volkmer, Nelson, McCandless, Mineta, and MacKay.

Mr. FUQUA. The meeting will be in order.

Without objection, permission will be granted to take photographs and recordings during the course of the hearing.

Today we welcome the space shuttle crew of flight 41–C, sometimes referred to as 41-Crippen, and more commonly known as the Ace Shuttle Repair Co.

In addition to the solar max observatory, now beginning a new life in orbit, they have left behind a massive, long duration exposure facility with some 57 experiments on board to be recovered next February.

The crew's service call in space has been a triumph of success-oriented thinking. A new era of space operations seems definitely to have begun. Throwaway satellites are no longer practical since most scientific satellites have become too costly and complex for a throwaway environment.

The commander of this historic mission and successful mission was a veteran of two previous space shuttle flights and scheduled to command one more later this year, Capt. Bob Crippen, and was very ably assisted by his teammates, pilot Francis Scobee; and mission specialist George Nelson, James Van Hoften, and Terry Hart, all three which did a very fine job as mission specialists.

Certainly, gentlemen, we want to congratulate you for what you did. It began to look like the repair mission was going to be a failure, and you and your support teams at Johnson and at Goddard Center worked to turn or snap the jaws—defeat out of the jaws and make it into a success.

And I also would like to introduce Frank Cepollina, who was the solar maximum repair mission manager for the Goddard Space Flight Center. I want to thank you, Frank, and all of the outstanding people at Goddard for the fine work and the professional manner in which you carried out your very vital role of this space flight. And please extend our congratulations to Dr. Hinners and all the fine people at Goddard for another job well done.

And last, but not least, let me introduce the wives of this fine crew who have also served and are often overlooked for their courage, their patience, and their fortitude in support of their husbands: Ginny Crippen, who, like many of us, has watched her husband Bob land the space shuttle at alternate landing sites in his last two missions.

Ginny, will you please stand. [Applause.]

June Scobee, we are pleased to have you. [Applause.]

Susie Nelson. [Applause.]

And Wendy Hart. [Applause.]

And Vallarie Van Hoften. [Applause.]

We're delighted to have all of you here, and we look forward to your report. But, before that, I'd like to recognize the ranking minority member of the committee, Mr. Winn, from Kansas.

Mr. WINN. Thank you, Mr. Chairman.

I, too, want to congratulate the crew of STS–41–C. Some of us are having a little trouble these days trying to figure out the identification and numbers and how you arrive at that. I think we're going to go back to such simple things as *Challenger* and *Enterprise,* and whatever new names you might dream up, instead of all these numbers. I guess we'd better talk to NASA about that.

Bob, I want to congratulate you and the crew again. We just had our pictures taken back there, and I said, "Well, sometimes I think that Bob will probably be on another flight before we ever get the pictures developed by NASA." I'll bet I get my pictures in the next few hours. [Laughter.]

But I'll tell you one thing about the delay and having to go to the alternate landing site, that it gave. While you guys were up there getting the bad news, why, the chairman and I and several members of the committee were on the ground getting much better acquainted with your wives and your families. So there are some good things that come out of those problems.

Let me say, too, that I remember, Crip, seeing John Young after he made the decision and came back down and said the weather was so bad you couldn't land, that he had proof positive with him. He had taken some photos and he went over and told Ginny that he was sorry they couldn't bring you down, but he showed her the pictures to prove why and what he based his decision upon. So that's the great thing—this is a real team.

And I want to congratulate you and, Frank, I want to congratulate you and the Goddard staff. They did a fantastic job. And even though we follow it more closely probably than many, many people in the country, the fact that you make a mistake or things happen, then we can turn it around and adjust and produce and make all the people of the United States and many, many people in the world happy with that type of production, and we really appreciate it. Thank you very much.

Thank you, Mr. Chairman.

Mr. FUQUA. Thank you, Mr. Winn.

Mr. Volkmer, chairman of the subcommittee.

Mr. VOLKMER. I just wish to join in the congratulations, and I think it was an outstanding flight and the accomplishments will show us the way in the future as to retrieval and repair of satellites. And we look forward to the future when we can go up and

pick up the two that didn't go up all the way on the previous, the other communications satellite, and, hopefully, in a year or so, when we can get off from Vandenburg, we can also pick up the Landsat that's not operating, and we can do a lot of other things. So we look forward to working with all of you together.

Thank you.

Mr. FUQUA. Thank you.

Bob, we'd be pleased to hear from you and your crew in whatever fashion you choose.

Again, congratulations to you and all of you for a very excellent mission.

STATEMENT OF CAPT. ROBERT L. CRIPPEN, USN, COMMANDER OF SPACE SHUTTLE FLIGHT 41-C; FRANCIS R. SCOBEE, PILOT; DR. GEORGE D. NELSON, MISSION SPECIALIST; TERRY J. HART, MISSION SPECIALIST; AND DR. JAMES D. VAN HOFTEN, MISSION SPECIALIST, ACCOMPANIED BY FRANK CEPOLLINA, SOLAR MAXIMUM REPAIR MISSION PROJECT MANAGER, GODDARD SPACE FLIGHT CENTER

Captain CRIPPEN. Mr. Chairman, members of the committee, thank you very much. It is a pleasure to be here today to give you a report on Mission 41-Charlie. And, Congressman Winn, you aren't the only one that has problems with the numbering system. We also do that, but as long as they tell us which spacecraft we're going in, we're prepared to go try it.

But the format I'd like to do today is to have each of my crewmembers go through and talk about some aspect of the mission very briefly, and then, as in the past, we brought a film that is sort of a good synopsis of the flight itself that we'd like to share with you. I'm very proud that you've brought Mr. Frank Cepollina from the Goddard Space Flight Center today because they were an integral part of this mission that did allow us to complete it successfully. And following the film, Frank will give you a brief scenario of where the solar max stands today.

So, with that, I'd like to turn it over to Pilot Dick Scobee and let him tell you a little bit about ascent.

Mr. SCOBEE. Well, the ascent phase, when you see the film, is probably no different from what you've seen before, but from our standpoint it was quite a bit different because we did the first direct insertion into orbit, which means that after the main engines cut off we didn't do an orbital maneuvering system burn. And so, right after main engine cutoff, which was at a much higher altitude and a larger elliptical orbit than we'd ever been in before, we sat and coasted for about 30 to 40 minutes before we burned our second burn, and that put us in elliptical orbit about 250 by 132 miles or so. And so, our view from up there was fantastic. It's the highest a shuttle has ever been, and so we got a very good view of the earth, and we used that as a phasing maneuver to get us in the right position for rendezvousing with the solar max satellite and putting out the long-duration exposure facility, both above 250 nautical miles.

So from the film, you won't see anything different, but from our standpoint, the procedures and everything, we did things a bit dif-

ferent. It was a very—from a crew standpoint, a better way for us to get into orbit because we weren't rushed into a burn right after main engine cutoff, and it gave us a lot of time and it gave us a lot of capability to tolerate underburns. If we had had the main engines not fire for the length of time they were supposed to, we had the capability of still attaining orbit even though we didn't have the proper velocity for rendezvousing and repairing satellites. It is a good capability for having in the orbiter program.

Captain CRIPPEN. And, of course, one of the primary objectives was to deploy the long-duration exposure facility, and Terry Hart was the officer in charge of that, so he'll give you a little rundown on it.

Mr. HART. Thank you, Crip.

As you point out, Mr. Chairman, we were pleased to take out the long-duration exposure facility, NASA's newest scientific satellite. It happens to be the largest payload the shuttle has taken up to date. It occupies about half of the payload bay and uses about half the shuttle's lift capacity. It's also about the least complex satellite we've launched. It has no altitude control system and no avionics as such, making it less expensive. In fact, the entire project was done for on the order of $9 million. However, there are 150 scientists from around the world from 9 different countries that participated in the 57 experiments onboard. The experiments were located in 86 trays that you'll see in our film.

They fell into two categories: material science; a typical material science experiment was the solar cell. There were a variety of different solar cells on one of the trays. They'll stay in orbit for roughly 1 year, and the scientists will be able to judge how they've degraded over the year and, hopefully, choose the best one for performance on future satellites. A large number of experiments were also in the category of space physics, collecting cosmic dust and micrometeorites.

As I mentioned, the payload is very simple. The shuttle's pointing capacity was used with the mechanical arm to leave the satellite in a very precise, stable orientation pointing toward the Earth, and we hope it will stay there for the 10 months it's on orbit.

We also did a rendezvous on the solar max, of course. It was the first rendezvous NASA has done since 1975. There were a couple things a little different about it. We have no lights on the solar max, and we also have no cooperation with the radar. That, plus the altitude and the fuel criticality of the shuttle at that altitude, required us to use a little different rendezvous profile than we've used in the past, but that all worked fine. And, in fact, we got a chance to do a second rendezvous on the fifth day of the mission.

Captain CRIPPEN. Of course, the reason that we had a chance to do the second rendezvous was that we were unsuccessful with the docking attempt with the maneuvering unit, and George Nelson was our prime maneuvering unit pilot, and I'll let him go through a little of those flight operations for you.

Dr. NELSON. On the third day, after the rendezvous with the satellite, the two extra vehicular crewmen, Jim Van Hoften and myself, went out into the bay on the maneuvering unit and, as you've heard from the flight 41-B report, the man maneuvering unit is really a fantastic flying machine that functioned perfectly

as far as compared to the training that we had had and the flyover to the satellite was very easily done and nominal.

Of course, we had a slight problem in that there was a small fiberglass pin protruding right above the trunion pin on the satellite which precluded the trunion pin attachment device that was mounted to the front of the maneuvering unit from attaching itself to the satellite, and in the process of flying against the satellite with the maneuvering unit we put some fairly good rates into the satellite, which then gave the folks at Goddard a chance to do their magic and stop the satellite from tumbling and gave us a chance to grapple it on the second day.

Captain CRIPPEN. And, of course, after we did manage to get close enough where Terry Hart could grapple it with the maneuvering—with the manipulator system, we put it in the bay, and both George Nelson and Jim Van Hoften performed very expeditious repair of the satellite, and Jim will tell you about that.

Dr. VAN HOFTEN. OK. Once we had it onboard, I think we had the easy part. We figured once we could get it onboard, the repair part of it was just like all the training we had done in the water tanks at both Marshall Space Flight Center and at Johnson. The repair consisted mainly of three aspects. We replaced the attitude control system, which was a 4-foot square box that weighs about 500 pounds, and this was meant to be done in orbit so it was a relatively easy task. The second was a small metallic plate that was clipped over a vent on one of the experiments onboard to prevent some rays, cosmic rays, and other things from getting into that port. And, last, we cut into the satellite itself to perform an operation which was not meant to be done in orbit, so we got a chance to show that things like this were possible.

It was an excellent way to show that "man-in-space" was really the only way we could have done this and repair the chronograph-polarimeter, an experiment which was later to be used to look at the flare that Mr. Cepollina will probably tell you about. We carried out these three jobs in about 4 hours, and we felt very good about it. We felt like the training we had had was very sufficient for this and that the task was easily doable in orbit. And we'd like to see more of this planned in the future.

Captain CRIPPEN. I guess one of the things that allowed us to be able to complete this mission successfully is something that I think is a byword for NASA, and that is to try to prepare ourselves for any contingency, not that we can forecast the contingency but we go through in our simulations and exercises any number of things that can potentially go wrong. Of course, it's never the thing that we forecast that can go wrong that does go wrong; it's always something unusual. But because we are prepared and used to handling things that are off nominal, we quite often can deal with them better. And it really proved once again that the team effort that we have, which in this case did involve the Goddard Space Flight Center, really pays off. Learning how to work together in simulations is a very productive type of thing.

And we thought we'd spent an awful lot of hours going through integrated simulations that did involve the Goddard Space Flight Center, but in my opinion it is only because that we did those that we managed to pull this mission off.

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Of course, as was pointed out, I had a chance to exercise the second waveoff, having done one on STS–7, from trying to land at the Kennedy Space Center. I'm afraid, Congressman Nelson, that some people may be getting the word that I don't particularly care to come back to Florida. That's not the truth. I enjoy being in Florida.

It turned out that on both of these occasions that the weather just was not suitable, in our opinion, for landing the shuttle.

I think that, once again, we did prove that the system is very versatile. We, in very short order, were prepared to turn around and bring the vehicle into the Edwards Air Force Base. That all went off about as smoothly as I think could be possible.

The orbit burn, which is the longest that we've done thus far since we had the space shuttle up higher than we've ever had it before, was completed nominal. The entry was essentially all in darkness because the landing was right at sunrise. We had the normal phenomenal light show that we get outside the windows that we all thoroughly enjoyed. George Nelson took some rather unique photographs that we'll show to you at the end of our film that will demonstrate that.

So, without any further ado, if we could turn down the house lights and roll the movie, it's much more fun than listening to us just talk.

[A film was shown during the following statements.]

Mr. SCOBEE. The initial part of this will look the same as it has before, but it was a fair amount different to us. You can see the shocks ejected when the main engines start, which is rather dramatic. And can we get some of the rest of those lights down?

Liftoff is very dramatic for the new guys. Crip's been through this several times. The four of us thought it was really a heck of a ride, and I thought it was real similar to riding a rough freight train. With the solid rocket motors going, it's very easy to see what's going on in the cockpit and everything. There is no problem functioning or anything like that, but it is a rough ride. And I can recommend it to anybody that's never done it and would like to go fly. It's really great.

Putting out about 6.5 million pounds of thrust and weighing about 4.5 million pounds at liftoff, and, as you all know, the solid rocket motors burn out in about 2 minutes. Thanks to long-range cameras, you'll get a fairly decent view of the motors coming off. When the separation motors fire, we do get—there they go right there—you do get some hazing of the windows, and the windows were perfectly clear up to that time. So when those motors fire, they put some residue on the windows of the orbiter which stay there for the rest of the flight; in fact, in subsequent flights.

This is a picture of the external tank coming in about 200 miles south of Hawaii, and it's rather dramatic. You can see the pieces breaking up there. It's at night, so it's low-light TV, so there's some blossoming in the picture that takes some of the effect away, but as the picture proceeds along, you can see some of the rather large pieces that come out of it. In a moment here you'll see—that's us coming right along behind the tank. If it hadn't been for the OMS burn, we'd be right behind it.

Captain CRIPPEN. This just goes through and proved that we're all onboard. We have to document that for the world.

Actually, Jim Van Hoften is using a large Lindhoff camera, the first time that we've flown one of those, that gives high-resolution photographs, that gave us some excellent Earth terrain photography.

Terry.

Mr. HART. We used Canada's mechanical arm to deploy the LDEF, and before actually releasing it we did pick up LDEF and move it around in different positions, much the same as we've done on previous flights, this time, of course, with the heaviest payload that it's had to move. And, you can push on the LDEF, it goes one way, but the orbiter goes the other way. It's really pushing on each other.

After release, which was right at sunrise in our orbit, about in the middle of the Pacific Ocean, we slowly backed away from LDEF, being very careful not to contaminate it or disturb its attitude. The end we're looking at is pointing toward space, of course. Its experiments tend to be micrometeorite, cosmic dust collection, things of that nature. The other end we hope will remain pointed at the Earth for the whole mission, and its experiments are likewise.

Captain CRIPPEN. We also carried a camera that's referred to as IMAX. Those of you who have been down at the Smithsonian saw that in "Hail, Columbia," that same camera, and they're going to produce a similar film using that that we shot here.

Mr. HART. We had nine rolls of film onboard, each roll 1,000 feet long, and only two magazines, so we used a black changing bag to put the subsequent rolls of film into the magazines.

We're getting ready for the rendezvous here on day three and, as we mentioned, that went just as slick as could be. The sensors onboard all worked fine, but we had total confidence in mission control, that they could have gotten us there.

Dr. NELSON. OK. We had the MMU checked out and started to fly over about one-half a foot per second out of the payload bay and toward the satellite. At this point it's a real comfortable ride coming out of the bay. We had done it in the training so many times that, outside of the spectacular view, it was just like flying the trainer.

There you can see the T-pad, the trunion pin attachment device, sticking out the front of the MMU there. That's the device that had the mechanical jaws that was meant to grab onto the trunion pin of the satellite. The trunion pin was a pin on the satellite meant to use for locking the satellite in the payload bay on return. It's about 3 inches long by 1½ inches in diameter. The satellite at this point is rotating at 1° per second. That's a view from the TV camera on my helmet. That was the same view that I had flying up there.

Flying into the satellite at very low rates was no problem. The MMU did blow a little bit of nitrogen onto the satellite and it made a very small perturbation in its motion, but nothing that the MMU couldn't fly out very easily.

OK. At this point you can see I went to go in. I think this is the final docking attempt, and hit the satellite, and the MMU bounces one way and the satellite bounces the other.

Captain CRIPPEN. When George bounced off the last time, it was obvious to me that we needed to try to use the backup system we had, which was to try to grapple it while it was rotating with the remote manipulator system or the mechanical arm. However, the grapple fixture itself is located under one of those solar rays, and the only way we could handle it is if it basically was rotating about its long axis, and we had to stop that pitching motion, which was the reason I asked George if he'd go out and grap hold of the solar ray to see if he could stabilize it.

Dr. NELSON. And we did that, and we did reduce the rate on the satellite by doing that—and hindsight is great. I think that we might have had a chance of stabilizing the satellite using that mode, but we did take some of the energy out of it to help the Goddard folks.

Captain CRIPPEN. Basically, when he came back away from it, you'll notice now it seems to be pretty much rotating about its long axis again, only it's rotating the opposite direction, but at least at that point in time I felt that it might be advisable to go in and try to grapple it with the mechanical arm. Unfortunately, we were not successful, so we elected to go ahead and, based on the excellent data given to us by the ground and the fact that Goddard thought they might be able to do something with it, which is contrary to what we initially thought, we backed out. And this is kind of what the satellite looked like when we were backing away from it. You can see that it's not only just a rotation, but it is more or less a big wobble about all axes, and it was very difficult to predict what was going to be presented to us next.

Dr. VAN HOFTEN. On the lighter side, we had a student experiment onboard with 3,300 Italian honey bees. These were put onboard with a control group on the ground to see if they'd make a honeycomb in space and what it might look like, and they did make a very large honeycomb that had some 30 square inches and produced, I believe, 35 eggs that the queen produced in there. They were extremely pleased with this. This was very similar, I guess, with the one that they had on the ground.

Mr. SCOBEE. This is just a real quick shot of some in-flight maintenance. We're removing panels with our EVA power tool, which turned out to be a really good thing on orbit. It saved us about one-third the time it normally takes to remove these fasteners and do the in-flight maintenance on cleaning our filters.

Dr. NELSON. Well, the shuttle, like most agencies, runs on paper, and we had a teleprinter onboard that every day the ground was very good during this mission at sending us very concise messages to change our time.

Dr. VAN HOFTEN. This is our means of exercise onboard. We had a treadmill that we can more or less simulate 1 g. It straps you down and we run about one-half hour a day apiece on that.

Captain CRIPPEN. After we essentially had a day off there while the Goddard people were working to get the satellite set up and stabilized, we were preparing to come in and do another rendezvous with it. I guess we learned a few things based on ground simu-

lations and drawing on just about everything that we knew to try to come in using as minimum fuel as possible in that second rendezvous, and the ground people again did super work, allowing us to make essentially a minimum fuel rendezvous.

Here comes Dick Scobee up to get in his seat. That's what I kept telling him before we got up there—it's always easier in zero g climbing around. In 1 g it's a little bit difficult, but it's nice in zero g.

As he indicated, we run on paper. It takes still about 60-some-odd pounds of books to go up and fly a mission.

There was the satellite as we were coming in on it. Unfortunately, I think the only place that we've documented the actual grapple was on a camera that we had located in the bay, which is the 360 camera, but you can kind of see it as we look out the overhead windows and out the right window. There's a little bit. You can see the actual arm moving in to get the grapple. We did grapple it successfully and placed it in the bay.

Dr. NELSON. At this point Jim Van Hoften and I got to do our thing. We carried three space suits onboard. This was Oscar, the third suit, which we took out of the airlock to make some room and did a short check on it. This shows how the space suit is put together. It really consists of just two major parts. There's a vest portion that contains a backpack and a pair of pants. It makes it very simple to put on, and it takes about 20 minutes from the time you start until you're ready to go outside.

It's nice, you can drop things there and they don't fall anywhere.

We had to maneuver the satellite on the flight support system—that was built by Goddard—that allowed us to tilt the satellite down and to spin it around to present the worksite to the front of the payload bay.

Dr. VAN HOFTEN. This is when we were preparing to go outside. This is in the airlock. It's a relatively small structure. Dick Scobee was our valet that would help us get dressed there. You can see the suits pretty much take up the whole area.

This is where I was on the end of the manipulator arm; we have a work platform that secures your feet to the end of the arm and it makes an excellent platform to perform this type of maintenance from. There's a large Goddard-supplied wrench there. It's a power ratchet wrench that is used to remove the attitude control system module. You can see how easy it is. Terry Hart would fly me around and into the arm, and all this was done just by verbal commands. You'd tell him you want to go up, down, right, left.

We would talk him into a position and then—using this tool, which just inserts into a conical tube—throw a few switches and we could basically unscrew the module from its location.

Captain CRIPPEN. One of the neat things is that those modules weighed about 500 pounds, or a little over, and they had no problem at all moving large objects of that nature.

Dr. VAN HOFTEN. This was working on the main electronics box on the satellite. You can see from my helmet-mounted camera all the wires and whatnot in there. There were some 11 connectors, each one of which had up to 78 wires coming out of it. So it turned out, after all that work we had done, it really wasn't that difficult to do, but we had had a lot of training and a lot of planning on

using the proper tools and how we could best do this, and it worked out quite well.

This is more or less a small computer that is not very large. It is about 1½ feet by maybe 1 foot. And we carried up a spare that was identical to it with a few modified parts, and basically all we did was put a hinge on this, pull it back, and then just put another one in its place.

Dr. NELSON. That's a good shot to show the foot restraint work platform on the end of the arm. One of the last things we did after the repair was to get a ride over the top of the satellite to take documentary photography.

Dr. VAN HOFTEN. After all this was over, we were clever enough to do it fast enough that I was able to do a ride also in the man maneuvering unit, to get an engineering test to look at some of the capabilities that we haven't had the time to check out so far, looking at center-gravity offsets and the like. It's quite a view up there.

As George said, the man maneuvering unit flies just spectacularly. It's a very valuable tool, I believe, that NASA's developed.

Mr. HART. The mechanical arm performed flawlessly the entire flight. This was the last task that we did with it, the release of the solar max, and we flew it to prescribed position and then pointed the tail of the orbiter toward the Sun, which pointed the solar max directly at the Sun, and then from the camera on the wrist here you can see the target we used to grapple payloads with, and this is the release of solar max. At this point we told Goddard that it was in free drift and they sent the appropriate commands to control the attitude of it from that point on.

Mr. SCOBEE. After that, we did a little bit of stationkeeping on the satellite while we did some of the checkouts, so we had the capability to go back and pick it up and return it to Earth if we needed to.

And then we did a separation burn using minimum fuel and got away from it, and we had lots of good help from the ground during that time period, also.

Captain CRIPPEN. One of the things you'll see there is an antenna that is deployed that will allow them to work and get more data through our T-bird satellite than we've been able to do before.

Dr. NELSON. Well, you have to eat on orbit. There's some shots here, just life in the cabin. It turns out that with the extra day we stayed onboard we did end up eating all of our food.

Captain CRIPPEN. Everybody was very neat.

[The film is showing the crew eating onboard.]

Dr. NELSON. This is how we drink coffee. [Laughter.]

And how we eat bananas. [Laughter.]

Captain CRIPPEN. That was a real rotating grapple right there [indicating the banana in the film]. [Laughter.]

Dr. NELSON. Zero g is lots of fun. As you might guess, it allows you to do things you can't do other places.

Captain CRIPPEN. But finally, we had to come home. I think it was appropriate that they let us land on Friday the 13th, anyhow, since we were originally at Mission STS–13. This essentially shows us all strapped into the seats, and that's what Pinkie shot there.

Dr. NELSON. I kept tapping everybody on the shoulder trying to get them to look out the window at this structure. There was a big

shock sitting over the center of the payload bay somewhere, and I held up the camera and took some pictures of it.

Captain CRIPPEN. That is not a part of the orbiter at all. That's strictly a shock wave.

Dr. NELSON. That's a pretty good representation of the color outside the window during entry. It's pretty warm out there. I did reach up and put my hand on the overhead window at one point and it wasn't warm.

Captain CRIPPEN. The landing was pretty much what we had seen before in the orbiter. It was just dawn out at Edwards Air Force Base, but the lighting was good after we were essentially overhead at around 45,000 feet. We could pick up all the familiar landmarks out there. We deployed the gear at about 300 feet. There was actually a puff of something that came out of the nosewell that I'm not really sure what that was, maybe just some little dust that had accumulated there.

We landed on Edwards lakebed, runway 17. It was essentially uneventful.

We hold off derotating the nose to about 180 knots. We modified the flight control system a little bit, such that you have much more control over the nose as it starts to fall through now, so it's a little bit slower than what we've seen on some of our previous flights.

We've had some problems with the brakes, and they were interested in making sure that we really got on the brakes, which I did, and stopped with no problem at all.

They were very expeditious about letting us come out, although we were still standing inside for about 15 minutes waiting for them to get everything all cleared for us.

There's five pretty happy guys there.

OK. That concludes the film. [Applause.]

I guess the two bottom lines are that we think that the shuttle is a very viable deployment vehicle for deploying satellites, both those that need their own boosters and those that we have to turn loose with our mechanical arms that stay in low Earth orbit. We've done that time and time again, and it continues to show us that it's super for those kinds of things. Perhaps more importantly, we think that we proved that satellite servicing is a viable capability of the space transportation system, and that worked out very well as far as we're concerned.

And I'd like to turn the microphone over to Mr. Frank Cepollina from the Goddard Space Flight Center, who was the manager of the solar max repair mission, to give you a status update on the solar max today.

STATEMENT OF FRANK CEPOLLINA, SOLAR MAXIMUM REPAIR MISSION PROJECT MANAGER, GODDARD SPACE FLIGHT CENTER

Mr. CEPOLLINA. Thank you.

Mr. Chairman, I'm really very, very happy to present my feelings and the feelings of the science community, the solar physics science community. We're just absolutely ecstatic with the success of the repair mission.

I'd like to point out a couple of technical parameters that we have seen in the last 4 weeks of spacecraft checkout and observato-

ry calibration, one of which is the—because we put a new technology attitude control subsystem onboard, our pointing accuracies are now a factor of two better than they were when we initially launched the solar max observatory, and our stability is improved by almost a half order magnitude.

These two features, coupled with the deployment of the TDRS antenna, which had been stored on the spacecraft since launch—we had not deployed it because TDRS wasn't up there and ready. We deployed it on this mission as part of the repair activity. But with those three features all coupled together, on the 25th of April, some 13 days after the repairs—there's something magic about the word "13;" it keeps cropping up. We landed on the 13th. We captured the spacecraft on the 22,013th revolution of the solar max, and so on. We just can't prevent it, even with 41-C.

But, nonetheless, 13 days after the repair mission we observed from ground-based observatories one of the largest flares that has occurred. As a matter of fact, it was 2½ times larger than any flare we had seen since 1978, and we had all three fine pointing instruments on working, plus the four course pointing instruments, and we happened to be using TDRS as realtime capability, and within 20 minutes the astronauts—excuse me, the scientists had commanded the satellite, which was then looking at the northwest corner of the Sun, down to the southeast quandrant, turned on all of the instruments, and started observing this gigantic flare eruption.

And they continued to observe it for 4 continuous hours, gathering 4 continuous hours' worth of data. This was never possible before in the normal G-Stiden type of spacecraft operational mode. So, everybody is very, very pleased about the operation of the system. Everything is working fine. We're very, very much encouraged and feel that we can go on this way for quite some time with new capabilities.

Thank you.

Captain CRIPPEN. That concludes our portion of the presentation. We'd be happy to try to entertain any questions you might have.

Mr. FUQUA. Thank you very much, Bob, and members of the crew, and also Mr. Cepollina, for the fine job that the people at Goddard did in making this such a success. We're just very delighted that it has been successful operationally after the repair. The repair was certainly an extraordinary feat, but the increased or resumed activity of the solar max mission further points out, I think, the viability and versatility of the space shuttle and what man can do in that type of environment. So, we want to congratulate you people again for the fine job that you've done, and to the crew.

You mentioned two things, not to steal Bill Nelson's question, which I'm sure he's going to ask. It's about the landing in Florida. I've missed you twice there, Crip, but we don't want you to land in bad weather.

But what impact do you think in the long range that will have? I realize that if it's rain, that causes a certain amount of damage to the tile, if you have to come through a rainstorm landing. But do you think that will be—can we improve that as time goes along, the ability to land there even with some inclement weather?

Captain CRIPPEN. Mr. Chairman, that certainly is something that we are looking at extensively. Our problem, as you pointed out, primarily is the idea of rain. We have proved to our satisfaction that to fly the shuttle with the thermal protection system we have with the tiles against any significant rain is going to do a lot of damage to the tiles themselves, to the point that it's at least going to be a major repair job to repair the space shuttle, and perhaps is aerodynamically going to affect it where we could not effect a safe landing. Consequently, we do not feel that we should take a chance on flying into a rainstorm if that possibility exists. I think most people would agree with us.

Cloud cover is another issue. We think we've got a good instrument system onboard. We're continuing to try to improve that where we would be able to fly it into a lower and lower cloud cover, but it's the idea of the rainstorms that is our primary concern.

We are working to try to improve our capability to forecast exactly what the weather is going to do. I'm sure that those of you that have been around the Florida coast know that the situation is very dynamic there and can change very fast. So, we have people working to try to improve that situation; but, we think that's essential, that we do not put ourselves in a position where we might have to fly into a rainstorm.

Mr. FUQUA. What—you mentioned the other question that I have, and that's about the brakes. I know you've had brake problems, not serious, but they have been aggravating.

Captain CRIPPEN. Yes, sir.

Mr. FUQUA. And I understand you—what was your rollout at this time when you were really applying the brakes?

Captain CRIPPEN. The total rollout distance on this flight from what would have been the end of the runway was just a little over 10,000 feet, and that was actually getting quite a bit of deceleration from the lakebed itself. By its very nature, it tends to brake you.

Mr. FUQUA. That was a rather long rollout there. Haven't most of them been less than that?

Captain CRIPPEN. No; that's about normal. The system is capable of stopping us even further than that. I was observing the braking profile that I had been given preflight.

Mr. FUQUA. But you didn't have—there was problem with the brakes this time?

Captain CRIPPEN. No, sir, we did sustain some——

Mr. FUQUA. I think the previous time they had a problem? Wasn't it once locked or didn't lock when they were rolling it out?

Captain CRIPPEN. We have sustained some damage on all flights, none of which impacted the actual stopping of the orbiter. They have been in varying degrees, and we did sustain damage again this time, again which had no effect on the actual stopping. And, the primary thing that we're concerned about is the reusability, because we have not been able to reuse them. And with the nature of the failures, there is always the possibility that it might impact a rollout. Consequently, we do have our engineers very concerned about that and trying to come up with a system that will alleviate that problem.

Mr. FUQUA. Thank you.

Mr. Winn.

Mr. WINN. Thank you, Mr. Chairman.

Crip, I don't quite understand what rain might do to the tile, when you figure out it's been engineered to withstand the heat now. Does it soften it up or what's their concern?

Captain CRIPPEN. I think if you were driving your automobile down the turnpike out here doing around 55 miles an hour and it was a pretty heavy rainstorm, and you stuck your hand out, you'd observe that it gets a pretty sharp impact. It's the fact it's a mass of the pellets themselves, and the faster you're going, the more that impact can cause damage.

There's a certain amount of mass in every raindrop, and the fact that the tile system themselves—it's very soft. Of course, you've seen that material, and it's about the consistency of styrofoam. And each pellet, if you're flying around, oh, say 300, 350 miles an hour, which we are, that's a pretty heavy impact, and what it does, it just eats into the tile itself. It's not a matter of softening so much as just impact damage.

Mr. WINN. Just beating it up.

Captain CRIPPEN. Yes, sir.

Mr. WINN. Pinkie, on that fiberglass article thing, when you were trying to dock, you couldn't see that? It's too small to see or——

Dr. NELSON. No; what the pin was, was a standoff for the thermal blanket that was covering the satellite, and the blanket went out to the end of the pin. So it was actually standing off about an inch off the skin of the satellite. And so it was, the thermal blanket was flush with the pin, and so I couldn't see it.

Mr. WINN. You couldn't see it at all?

Dr. NELSON. No.

Mr. WINN. When you came in there, we were watching it on TV. Did—what did it do, bounce you away, push you—bounce you back?

Dr. NELSON. It was pretty much just an elastic collision with the satellite. As the T-pad went in, it was just a bounce and right back off again.

Mr. WINN. How many times did you try it, two or three?

Dr. NELSON. I tried three times.

Mr. WINN. Three times. And was it—was the sensation, the feel that you were getting, basically the same thing each time?

Dr. NELSON. Yes; they were all very similar, and I just increased the rates each time. My original thought was that it was a malfunction in the T-pad itself, in the grappling device, but it turned out not to be the case.

Mr. WINN. Thank you.

Thank you very much, Mr. Chairman.

Mr. FUQUA. Thank you, Mr. Winn.

Mr. Brown.

Mr. BROWN. Mr. Crippen, can you say anything about additional repair missions that might be susceptible to action from the shuttle? For example, is there any thought that this could be done with the space telescope after it's launched, or what would be the problems with some of these communications satellites that haven't gone into orbit? The shuttle doesn't have the capability to move out of low Earth orbit, I suppose, to handle these, but can you speculate about what the prospects might be for additional missions?

Captain CRIPPEN. Well, we are looking at potential missions that might utilize this capability; we think that will enhance and reduce the cost of satellites in the future.

The space telescope you mentioned, in particular, is designed to be serviced by the space transportation system. It is the intent to rendezvous with it periodically, resupply it with whatever the consumables that it needs, and if potentially there is a repair required to do that, it's also designed to take modules out, replace modules, to put in new scientific observing experiments. So that one was designed with that in mind, than we would be able to utilize that.

NASA right now is looking at the Landsat-D satellite, which is in polar orbit, was mentioned earlier. The limiting consumable onboard that is the fuel, the hydrozene that we use to maintain its energy control, and quite a few satellites today are limited by the amount of their usefulness because they run out of propellant. Consequently, we are trying to develop a system where we can refuel satellites on orbit. On my next flight, we're going to test out the capability to actually transfer hydrozene. And, we are looking at if it's possible to actually go up and rendezvous with the Landsat satellite and reservice it as far as fuel is concerned. It has undergone some malfunctions which we would be talking about trying to do some repair on the satellite as well. So that is one that we are looking at.

The two communications satellites that had the problem on the flight prior to ours, people are speculating about whether it's reasonable to go up and try to retrieve those satellites. I don't believe we're talking in terms of repair because the problem is not—at least we do not think that there's any damage to the satellites, but rather that they didn't get in the original orbit. That's still being analyzed by NASA. And of course, if we did it, it would have to be at the request of the customers themselves. So that, as far as the feasibility, it's still being analyzed, and I wouldn't care to speculate on whether that might be a reasonable thing to do.

Of course, most of our communications satellites do end up in geosynchronous orbit, which is up over about 23,000 miles, and today the space shuttle is not designed to go to those altitudes, but in the future, someday we will have a vehicle and man will go up to do servicing on those kinds of vehicles.

Mr. BROWN. What would be the limiting feature or fact with regard to the shuttle's orbital capability, the amount of fuel it could carry?

Captain. CRIPPEN. We're limited on altitude that we can get to, strictly by the amount of payload. We can trade off payload for fuel to get us to a higher altitude. Today we talk about around 300 miles, which is about the altitude that we flew on this last flight, as being around the maximum. We could have gone a little bit higher with less payload. So those are the kinds of parameters that we're talking about.

Of course, going into polar orbit, where the Landsat is, the fact that you're flying across the equator instead of essentially along the equator, you can't take advantage of the energy that you get because the Earth is rotating, so you lose some performance and can't go quite as high on a polar orbit as you can flying out of Kennedy essentially in an equatorial orbit.

Mr. BROWN. Thank you.
Mr. FUQUA. Mr. Skeen.
Mr. SKEEN. I have no questions, Mr. Chairman.
Mr. FUQUA. Mr. Volkmer.
Mr. VOLKMER. Thank you, Mr. Chairman.
I have a couple questions.
Bob, I talked to you very briefly about a news report that was out, and I know certain people probably saw it, about the use of the personal hygiene or toilet facilities on the shuttle and problems with it. Could you discuss that very briefly? I think you know of the reports that were made, and I'd like to maybe set at ease some of the people's minds.
Captain CRIPPEN. Yes, sir; I think that most people grasp that particular part of the orbiter because they can at least relate to it. [Laughter.]
Mr. VOLKMER. Yes, everbody does it.
Captain CRIPPEN. The waste management system has been essentially an annoyance, I would call it. We have had some problems with it, but I was pleasantly surprised on our last flight at the positive steps that had been made. There have been modifications in the system that have improved its operation considerably. There are also other aspects of its operation that do need to be improved. They are more or less of an annoyance nature. We have come back and we have talked with our engineers and they're working to try to improve them. Consequently, I feel fairly good about the system itself, that we are taking strides in the right direction.
Mr. VOLKMER. And we'll be able to, hopefully, take care of the problems if we go to—when we go, I should say—to a manned space station that will be in longer terms of orbit?
Captain Crippen. We've worked these kinds of problems in the past. Of course, with Skylab we had a system that could sustain operation for up to 3 months and could have gone even longer than that. It so happens the particular system we've got right now was not designed to go for very long periods of time, because the shuttle was not supposed to be up for those kinds of periods. Consequently, the system does have some limiting factors that we need to work on.
Mr. VOLKMER. I'd like to ask you, also, I notice that you're all enjoying eating onboard and experiences with it. You also receive, do you not, packages of food that are prepared food in foil, meats and things like this?
Captain CRIPPEN. Yes, sir; we do. Maybe George Nelson could talk about those.
Mr. VOLKMER. I'd like somebody to tell me how they taste and things, because the rest of us don't get to eat that. I was just wondering. It's not available.
Dr. NELSON. Opinion varied from person to person. I thought the food was pretty good. A lot of it's reconstituted, so you just add water. It's a lot like the freeze-dried food you take camping. Some of it—we have some meat that's packed in foil, that we have a little—not an oven, but a heater onboard where we can get the food up to 100 degrees or so that makes it pretty good. We ate it all. We were out of food by the time we came back.

Mr. VOLKMER. Was any of the food that you received such as the meats, such as medium rare steaks, or stuff, already prepared that you just heat it up; you didn't have to actually cook?

Dr. NELSON. No; we didn't actually do any cooking at all. We don't have the facilities to do that. It's all just heated up.

Mr. VOLKMER. Right. You just heated it up; right?

Dr. NELSON. Right.

Mr. VOLKMER. This was brought to my attention in the gentleman from California's subcommittee while we were looking into food preservations, et cetera, about irradiated food.

Dr. NELSON. Yes, we carried quite a bit of irradiated food onboard.

Mr. VOLKMER. I was wondering, how does that taste? In other words, we don't get to eat it. Nobody else in this whole country gets to eat that food?

Dr. NELSON. Is that right? [Laughter.]

Mr. VOLKMER. I don't know if you knew that or not.

Dr. NELSON. I thought it was acceptable to me.

Captain CRIPPEN. I don't think from a taste standpoint that you notice the fact that it's irradiated. They can take a steak, go out and charcoal broil it, and radiate it to kill all the germs, put it in a foil container which is essentially sterilized, and put it on the shelf for 4 or 5 years, and when you open it up, it tastes like a steak to me.

Mr. VOLKMER. But, see, our problem is that FDA says that the rest of us can't have that; says it's not proven out.

I was just wondering—none of you got sick from it or anything else, and you're all feeling fine; is that right?

Dr. NELSON. That's correct.

Mr. FUQUA. And still alive today.

Mr. VOLKMER. I think maybe we can talk to the FDA about it, and maybe the rest of the world can, the rest of the people in the country can enjoy it.

Mr. BROWN. But they glow in the dark.

Mr. VOLKMER. They glow in the dark now. [Laughter.]

Captain CRIPPEN. NASA is very concerned about the amount of radiation that the astronauts come under because of the fact that we are up above the earth's atmosphere; we do get more radiation, and there's essentially no radiation coming from the food.

Mr. VOLKMER. Dr. Nelson—George—on the—I'd like to ask, as the gentleman from Kansas did, on the trunion pin, now what was it exactly? Was there a piece sticking up? It's a round cylinder pin; right?

Dr. NELSON. Yes, a trunion pin's about this big [indicating small paper cup]. And what there was was a fiberglass—yes, here we are; I can build you a little model [Captain Crippen hands Dr. Nelson a pen]. There's a little fiberglass pin sticking up like this on the edge of it, and——

Mr. VOLKMER. In other words, it wasn't on the trunion pin itself; it was right atop or below or somewhere along the side of it?

Dr. NELSON. Right; and the trunion pin attachment device was a cylinder which fit over, and it had to fit on a certain distance in order to fire the jaws. And with the position of this pin, we were

about four-tenths of an inch shy of ever hitting the trigger on the T-pad.

Mr. VOLKMER. OK. Now where did the arm, Terry, the arm actually grapple to the solar max?

Mr. HART. There's a grapple fixture that's designed specifically for the mechanical arm, to grab ahold of the payload. That, of course, was put on prior to launch of solar max. It was the first satellite to be equipped so. That location was underneath one of the solar rays, which gave us fits from the tumbling on the third day of the mission. By the fifth day, Goddard had taken those rates and converted them all into one axis, which causes those rays to go around in the same plane, and that's the way essentially we had trained to grapple with the arm and that was very much—very comfortable for us on the fifth day.

Mr. VOLKMER. So you really had no difficulty, then, with grappling.

Mr. HART. Not on the fifth day. On the third day we were on the limits of the capability of the arm and myself to maneuver it fast enough to catch up before reaching the reach limits of the arm.

Mr. VOLKMER. Thank you very much, Mr. Chairman.

Mr. FUQUA. Thank you.

Mr. Nelson.

Mr. NELSON. Let's talk about the weather, Crip. Do the thermal blankets have any added protection against descent through rain?

Captain CRIPPEN. They don't have the same problem that the tiles do, but it so happens that the thermal blankets are essentially on the top and around the fuselage of the orbiter, and the bottom of it, which is the part that is still exposed to the rain, is still with the tiles.

I'm really not that familiar with what would happen with the blankets, but I don't believe we'd have a similar kind of a problem.

Mr. NELSON. Do you expect any aerodynamic differences on *Discovery,* the fact that it will have more blankets as opposed to tiles?

Captain CRIPPEN. That is still a matter of some speculation. The engineers tell us that it should be essentially nil, if there is any. It so happened that on our last flight we had to borrow one of the orbiter maneuvering system pods for one of the areas back in the rear end of the spacecraft from the *Discovery,* which did use those blankets. And essentially we didn't notice any significant difference. There was some firing of jets that was a little bit in excess of what we had anticipated around MOC–6 that might have been due to either the drag difference of the pods, but it was also true that the pod itself was a little bit different size. So those are some things that we're analyzing.

But it is also because there are some unknowns associated with it that myself and quite a few other people have agreed that the prudent thing to do with the first flight of any new vehicle is probably to land it on the lakebed out at Edwards where it offers quite a bit of room for error.

Mr. NELSON. When do you get your first landing on the autoland system?

Captain CRIPPEN. That landing is scheduled on the flight after the next. Colonel Bobko is scheduled to do that, and that flight is scheduled in August at this time.

Mr. NELSON. Since certain times of the year that the buildups may occur in the early morning, it has been suggested by Dick Smith that the time when it is almost universally, except in times of severe storms, clear weather is in the early morning dark hours. Now that we've already done a night landing, that could be just as routine as a landing at 7 a.m.; could it not?

Captain CRIPPEN. We are certainly prepared to do night landings based on STS-8, what we've seen there. The problems that we're faced with is the time that we can land is dictated by the orbit that we're in and when we lifted off, which is driven by whatever the user is of the satellite itself, so sometimes we don't have that option of landing at that particular time.

The other is that it is very difficult for us to evaluate what the actual weather is in the dark. I found that out when I was doing the flight for STS-8 and the night flight itself. It's just hard to go out and ascertain what it is.

So both of those things make us a little bit reluctant to say yes, that's the way to solve the problem. But I have to agree with you, that time of the day is a little bit better, although we have also seen fog setting in about those periods of time, too.

Mr. NELSON. Thank you, Mr. Chairman.

Mr. FUQUA. Mrs. Schneider.

Mrs. SCHNEIDER. My colleagues have focused on some of the technical questions. I'd like to focus for a moment on some of the economics questions.

Ten years ago when—I guess it was about 10 years ago when the Space Shuttle Program was getting under way—what was the original estimated cost of the program?

Mr. FUQUA. I don't think—we can get the information, but I don't think that the crew is prepared to answer a question like that.

Captain CRIPPEN. Yes, I'd be speculating. We've got some other people that are much better prepared to answer those questions.

Mr. FUQUA. We're really trying to talk about their flight——

Mrs. SCHNEIDER. Fine.

Mr. FUQUA [continuing]. And that, because they're not prepared to answer something of that——

Mrs. SCHNEIDER. Fine. I'll hold on until we find someone who is prepared to answer that.

Captain CRIPPEN. We have people that can give you that.

Mrs. SCHNEIDER. How about——

Mr. VOLKMER. If the gentlelady would yield, we have our annual reauthorization hearings and we also, if she has these questions, could direct them to subcommittee staff, and we'd be glad to provide the answers for her questions.

Mrs. SCHNEIDER. Very fine. Thank you.

How many more flights are anticipated for the remainder of this year of the shuttle?

Captain CRIPPEN. OK. At the current time, we have four flights scheduled for this calendar year. Right now it's essentially two in this fiscal year.

Mrs. SCHNEIDER. And we've done how many already——

Captain CRIPPEN. We have launched——

Mrs. SCHNEIDER [continuing]. This year? Two?

Captain CRIPPEN. Two, two this year.

Mrs. SCHNEIDER. OK. Thank you.

I have no further questions, Mr. Chairman. Thank you.

Mr. FUQUA. Thank you very much.

And, Crip, thank you very much for you and your crew and your supporting crew behind you [referring to the crew's wives].

I want to congratulate all of you and also, Frank, the folks out at Goddard and all the others that participated in a very historic and important mission.

Thank you very much for being with us today.

The committee is adjourned.

[Whereupon, at 12:09 p.m., the committee recessed, subject to the call of the Chair.]

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